PREPARING FOR THE NEXT FRONTIER – DISTRIBUTION SYSTEM OPTIMIZATION PLANS

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ABSTRACT

The operation and management of water distribution systems plays a critical role in a utility's ability to provide safe drinking water to its consumers. For the last two decades, major efforts have taken place to improve source water treatment. Recently, the emphasis has expanded to include not only improvement of water treatment, but also conveying and distributing high quality water to the consumers' taps. From a regulatory standpoint, the proposed Revised Total Coliform Rule will require a stronger emphasis on the distribution system, and the EPA is considering a Distribution System Rule that would potentially focus on implementing, demonstrating, and documenting Best Management Practices in the Distribution System.

In response to the focus on distribution system water quality and risk minimization, utilities are beginning to plan for a potential DMOM (Distribution Management, Operations, and Maintenance) program, similar to the CMOM programs that many utilities have implemented for their sewer collection system. A recommended first step toward implementing a DMOM program is to prepare a Distribution System Water Quality Optimization Plan (DSOP), a tool developed by the Water Research Foundation (WRF). A DSOP is a plan for maintaining water quality throughout the distribution system. It is a working document that organizes and integrates all policies and programs affecting water quality in the distribution system.

This paper provides owners, engineers, and regulatory personnel with the drivers for optimized distribution system management, an overview of the WRF's DSOP process, and the benefits the DSOP process has brought to Winston-Salem City/County Utilities Commission.

KEYWORDS

Distribution System Water Quality, Distribution Management Operations and Maintenance (DMOM), Distribution System Water Quality Optimization Plan (DSOP), Benchmarking

INTRODUCTION

The operation and management of water distribution systems plays a critical role in a utility's ability to provide safe drinking water to its consumers. For the last two decades, major efforts have taken place to improve source water treatment. Recently, the emphasis has expanded to include not only improvement of water treatment, but also conveying and distributing high quality water to the consumers' taps. The City of Winston-Salem City/County Utilities Commission (CCUC) has invested heavily in expanding and improving its source waters and treatment capability and reliability, and recognizes that there is also value in bringing the water distribution system up to that same operational level to achieve CCUC's Mission. The mission of the CCUC's Utilities Division is to treat and distribute water and collect and treat wastewater in compliance with all State and Federal regulations, and maintain one of the lowest cost to customers of any major system in North Carolina. In support of this mission, CCUC developed a Distribution

System Water Quality Optimization Plan (DSOP) to provide the blueprint for continual improvement of the water distribution system through identified distribution system optimization programs.

Optimized Distribution System Management Drivers

The drivers for developing a DSOP include regulatory compliance, public health protection, risk reduction, and efficient operation. From a regulatory standpoint, the proposed Revised Total Coliform Rule (RTCR) will require a stronger emphasis on the distribution system. The USEPA decided to revise the current Total Coliform Rule at the end of its second six year review. This rule focuses on the prevention of microbial contamination in the distribution system. The drivers for the RTCR are better public health protection, increased effectiveness of monitoring requirements, and more effective corrective action strategies. Thus, distribution system integrity will be very important. The proposed draft RTCR was announced in June 2010, is planned to be finalized in 2012 after the public comment period, and is anticipated to take effect in 2015.

A formal program for continued research on distribution system risks was established in 2009, EPA partnered with the Water Research Foundation (WRF) to form a Research and Information Collection Partnership (RICP). The RICP developed a document that identifies the following 10 high priority, science-driven, mutually-agreed-upon, strategically-focused, and decision-relevant research and information collection project areas:

1. Survey of large drinking water utility distribution systems.
2. Epidemiological studies of health effects associated with low or negative pressure events in distribution systems.
3. Quantitative Microbial Risk Assessment (QMRA) to evaluate exposure to pathogens through drinking water distribution systems.
4. Contaminant entry breaches in storage facilities.
5. Estimation of contaminated water volumes and contaminant concentrations introduced into the distribution system, due to backflow events from unprotected cross-connections, based on model predictions and field and pilot-scale experiments.
6. Survey of distribution system pressure management practices.
7. Characterize propagation of pressure events through water distribution systems to improve pressure management approaches.
8. Targeted surveys to obtain information on state and local regulations, policies, manufacturing practices, and guidelines for distribution systems.
9. Best practices to minimize risks associated with cross-connections and back-flow.
10. Best practices to minimize risks associated with storage facilities.

Furthermore, the EPA is considering a Distribution System Rule that would potentially focus on implementing, demonstrating, and documenting Best Management Practices in the Distribution System. In response to the focus on distribution system water quality and risk minimization, the American Water Works Association (AWWA) has revised ANSI/AWWA Standard G200-09, Distribution Systems Operation and Management, that utilities may use to improve distribution system practices.

In a 2006 National Research Council Report, *Drinking Water Distribution Systems: Assessing and Reducing Risks*, the following areas are listed as the ones with emerging issues related to public health risks and categorized as high priority or medium priority:

High Priority	**Medium Priority**
Cross-connection and backflow	Biofilm growth
New and repaired water mains	Loss of residual via water age and nitrification
Finished water storage	Low pressure transients and intrusion
Premises plumbing	
Operator training	

The Partnership for Safe Water (Partnership) recently developed a voluntary Distribution Systems program, based on criteria developed by WRF for optimization of water distribution system operation (WRF 2010). The Distribution Systems program includes performance goals for chlorine residual, pressure management, and main break frequency to ensure water quality preservation, hydraulic reliability, and physical security.

DSOP addresses the need for improvements in operational efficiency by benchmarking practices and procedures and focusing resources where they are most effective from a water quality standpoint.

Distribution System Optimization Plan (DSOP) Objectives

The DSOP is a tool that utilities use for evaluating and improving programs that affect distribution system water quality; evaluating conditions within the distribution system; creating better documentation; and enhancing communication between the various utility functions that impact distribution system water quality. This plan addresses both regulatory compliance issues and customer issues related to aesthetic properties of drinking water.

Specific DSOP objectives include:
1. Evaluating how existing operating, maintenance, monitoring, treatment, and other distribution system water quality management practices compare to current industry best management practices.
2. Documenting existing practices and protocols.
3. Developing a prioritized list of practices and potential projects that will enhance system operations.
4. Developing a roadmap for implementing recommended improvements.

Winston-Salem City/County Utilities Commission specifically developed the following goals for their DSOP development:
1. To continue to meet current regulations and anticipate future ones.
2. To have metrics so CCUC can prioritize where to put resources.
3. To fulfill the need for documentation of the practices and procedures in the water distribution system.
4. To help CCUC to optimize allocation of financial and human resources in operating the distribution system.
5. To use the results of this DSOP to help support the ongoing efforts by CCUC to develop and implement its asset management program.

METHODOLOGY

The approach to developing the DSOP includes the following tasks:

1. Review existing information including the department structure, water quality results and reports, operational practices and procedures, maintenance practices and procedures, cross-connection control program, distribution system pressure/mixing zones, consumer confidence reports, and any other reports or special projects impacting water quality.

2. Conduct staff interviews to gain a thorough understanding of current distribution system practices. A diverse cross-section of staff should be interviewed, for the CCUC project key employees related to water quality monitoring, operations, cross-connection control, construction, engineering, and management were included.

3. Analyze the data and compare it to industry best management practices. The *Criteria for Optimized Distribution Systems* report (WRF 2010) includes matrices with over 120 best management practices, focused on the areas of Management and Training, Strategic

Planning, Water Quality Control and Monitoring, Engineering and Facility Planning, Operations, and Maintenance.

4. Develop Preliminary Recommendations and Rank Improvements. Assign priority levels (high, medium, and low) based on the potential to enhance water quality throughout the distribution system, preclude quality degradation in localized areas, and resources available for implementation. Rank the relative level of effort required for implementation (A through D), with "A" indicating minor modifications needed to an existing program and "D" indicating no program exists.

5. Prepare a Summary Report that documents the audit findings, summarizes the recommended initiatives and planning level costs, and provides a roadmap for continual improvement.

6. Conduct a workshop with the project team members to present and review the draft findings.

RESULTS

CCUC's practices were evaluated and compared with the best management practices in the water distribution system industry. This analysis revealed that CCUC maintains its distribution system in general accordance with industry standards.

Programs Consistent with Industry Standards

CCUC's programs that conform to or exceed the industry best practices include:

Engineering, Planning, and Management

- *Capital Planning:* CCUC is to be commended for its recent planning effort in developing a treatment and distribution system master plan based on existing hydraulic and water quality conditions and future growth projections. This Master Plan document provides a good roadmap for future improvements.

- *Water Flow and Pressure:* The identification of pressure zones and areas in the Master Plan that need improved fire service, pressure, and flow is a necessary first step in maintaining and improving service. It is likely that a prioritization of those improvements will be necessary as funding becomes available to make those changes.

- *GIS:* The consolidation of GIS activities into a compact unit is commendable, as is the progress being made in entering sewer system data. The planned emphasis on enhancing the data entry through outside contracting should help speed the entry of more data, increasing efficiency of operating entities that rely on this data and the GIS program.

Water Quality

- *Additional Monitoring:* Besides TTHM, HAA, free chlorine residual, and lead and copper samples, the following analyses are conducted for more effective system operations and maintenance:

    - pH (~20 locations every month)
    - Turbidity (~20 locations every month)
    - Conductivity (~20 locations every month)
    - Alkalinity (~20 locations every month)
    - Hardness (~20 locations every month)
    - Fluoride (~10 locations every month)
    - Orthophosphate (~10 locations every month)
    - Calcium (~10 locations every month)

- Iron (~25 locations every month)
- Sodium (~10 locations every month)
- Manganese (~10 locations every month)
- Zinc (~20 locations every month)

- *Continuous Monitoring Stations:* There are three continuous monitoring stations that measure free chlorine residual and temperature.

- *Dedicated Sampling Stations:* In order to enhance the accessibility to the sampling points and eliminate the interruptions of sampling, CCUC has installed 14 dedicated sampling stations, corresponding with the Stage 2 DBPR monitoring locations. Due to the potential changes in the RTCR, the sample location selection and integrity of the sampling locations are becoming increasingly important. CCUC is planning to install 22 more stations.

- *Data Management:* Perkins Elemer Labworks Laboratory Information Management System (LIMS) is used for the management of the laboratory results. The samples are scheduled and a barcode is generated for each sample.

- *Consumer Inquires:* The customer service program, City Link, is responsible for taking customer inquiries and creating service requests for water quality. All calls are recorded by the call center. When the calls come in they are logged in, assigned a service request number, and routed to appropriate personnel via email. Water quality and O&M staff have access to the system to update the status of requests, create work orders if further work is required, record what action is taken, and close the requests when the inquiry is addressed.

Operations and Maintenance

- *Water Storage Facilities*: The operation and maintenance of finished water storage facilities is consistent with and exceeds industry practices. The 5-year inspection and cleaning frequencies are consistent with industry norms, the refurbishing with epoxy coatings is exemplary, and the operation for water quality maintenance is appropriate.

- *Piping – Break and Leak Repair:* Based on the description of repair activities provided by field supervisors and staff, many of the practices used are within industry norms; however, practices are inconsistently applied from crew to crew.

- *Water Main Flushing:* The three approaches to water main flushing appear to be meeting the objectives of maintaining water quality for regulatory compliance and aesthetic improvement, and are generally consistent with industry standards. Efficiencies could likely be gained by consolidating and organizing the three programs into one.

Opportunities for Improvement

CCUC's programs that did not meet industry best practices, and present opportunities for future emphasis, include:

Engineering, Planning, and Management

- *Standard Operating Procedures:* The development of SOPs for operations and maintenance of the distribution system is needed and would improve efficiency by having staff focus on essential aspects of the activity, and would improve the consistency and quality of the final product among the various crews and from site to site. In addition, these SOPs would form the basis for a more formalized training program for operating staff.

- *Formalization of Training Based on SOPs:* The current approach of emphasizing "On the Job Training" and AWWA training programs is good, but the added element of using SOPs as a basis for specific training of staff would further enhance the program and effectiveness.

- *Water Main Replacement and Renewal:* It would be advantageous to develop a condition assessment and criticality-based replacement and renewal program for water distribution system components. The coordination of water main replacement with other programs such as sewer replacement and paving is good, but the water distribution system is of great value and merits its own replacement and renewal program to ensure its continued serviceability.

- *Cross-Connection Control Program:* The ongoing transfer of the Cross-Connection Control Program to more of a customer-driven program needs to occur thoughtfully and with assurances that the level of abatement and compliance continues at a high level. CCUC will need to document how the program will be enforced and compliance documented. Cross-Connection Control is considered very important by Federal and state regulatory agencies, and there will likely be increased regulatory oversight and emphasis in the near future.

- *Water Loss Control:* The International Water Association (IWA) has developed a new standard method for calculating water loss, adopted by AWWA. The IWA/AWWA Water Loss Accounting System assigns water to ten categories, to more accurately determine authorized consumption and water loss. This system can help CCUC develop a more effective strategy to minimize water loss.

- *Metering:* Malfunctioning meters can mean lost revenue to a water system. Necessary periodic tests and calibration of meters will increase the accuracy of metering and be advantageous as a water loss program is developed. AWWA Manual M6 (Water Meters - Selection, Installation, Testing and Maintenance) suggests that a good meter record system should be in place for basic data for each meter. A written Repair and Replacement Program that includes cleaning and disinfection procedures would also help CCUC to establish a consistent water quality protection approach as the new automated meter replacement program is implemented. The AMR system will be helpful in strengthening CCUC's tracking of unbilled, authorized consumption in the future.

Water Quality

- *Revised Total Coliform Rule:* The proposed RTCR strengthens the current TCR by putting more emphasis on sample site selection, MCLs for Total Coliform and *E.Coli,* Assessment, and Corrective Action. It would be beneficial for the water quality staff to review the plan for their current TCR sampling and evaluate if the sampling locations reflect the water quality profile of the distribution system. Also, new methods for measuring TC and *E. Coli* are being evaluated. Once EPA decides which methods will be accepted in the RTCR, the laboratory certifications should be confirmed.

- *Dedicated Sampling Taps:* In the RTCR, installation of dedicated sampling taps is listed as one of the corrective actions a utility can take. This is recommended since it minimizes the occurrence of contamination that can result from improper sampling. Also, these stations can provide improved access to the sampling site. CCUC has already installed 14 stations and is planning to install 22 more. As more funding becomes available, it would be beneficial for CCUC to install additional sampling stations.

- *Public Notification Plan:* A Public Notification Plan is available for the water treatment plants; however, a plan for the distribution system does not currently exist.

Operations and Maintenance

- *Standard Operating Procedures - Documentation:* There is little or no documentation in the form of SOPs for most of the activities in the distribution system. SOPs are needed to help determine which parts of the job are to be done, what sequence is needed, what if any metrics are important, and who is responsible for what part of the job. SOPs make for a more efficient operation, eliminating procedures that do not contribute to the quality of the final product and enable the worker to focus on the important parts of the job. SOPs facilitate training and increase consistency of the work product among various crews and from job to job.

- *Valve Operation and Maintenance Program: The* most important need that the distribution system has is a comprehensive, organized, and adequately funded valve operation and maintenance program. The program should be based on a criticality assessment, starting with the most critical valves first, then moving on to line valves. This valve program forms the basis for good system operation and facilitates shutdowns and maintaining adequate pressures throughout the system during normal system operations and emergencies.

DISCUSSION

The DSOP process has proven beneficial to Winston-Salem City/County Utilities Commission, and has already resulted in the following benefits:

1. Better understanding of the state of the distribution system.
2. Working documents that can grow with the system.
3. Increased awareness of deficiencies, leading to more conscientious decision making.
4. Intelligent guide to improving maintenance programs.
5. Served as reminder to keep staff focused on priorities and goals.
6. Aided in the reorganization of staff for future and current needs.
7. Implementation of SOP's has improved the learning curve for new and transferred employees.

CONCLUSIONS

This project included an evaluation and assessment of engineering, planning and management (EP&M); water quality (WQ); and operations and maintenance (O&M) functions. Representative staff from each functional area was interviewed, and strengths and weaknesses were identified. Existing practices were compared to industry standards and areas that need further improvement were identified.

The DSOP project revealed that CCUC maintains its distribution system in general accordance with industry standards; however, some areas could benefit from enhancements. These areas have been categorized based on their criticality for CCUC's distribution system, as shown in Table 1. "High Priority" areas should be addressed and included in short-term projects. Improvement in the "Medium Priority" areas would help the operations of the distribution system, but can be integrated into longer-term projects. "Low Priority" are the areas where CCUC has been making improvements for a while and should continue these efforts until the programs are successfully completed.

In addition to the priority rankings, development levels were assigned (defined in the table footer) to reflect the estimated level of effort required to achieve the recommended improvement.

Table 1- Prioritized Areas for Improvement

	Development Level	EP&M	WQ	O&M
High Priority				
Valves – Implement a comprehensive valve exercising and maintenance program	C			X
SOPs – Develop formal written Standard Operating Procedures for distribution system activities	D	X		
Job Specific Training – Provide for formal training for distribution system staff based on SOPs	C	X		
Cross Connection Control Program – Ensure smooth	C	X		

Table 1- Prioritized Areas for Improvement

	Development Level	EP&M	WQ	O&M
transition to external/private system				
Revised Total Coliform Rule – Determine if additional sampling locations and laboratory certifications will be required, and prepare accordingly	A		X	
Medium Priority				
Water Main Flushing Program – Formalize system-wide flushing program, to improve coordination of activities from the three flushing triggers	B			X
Develop a condition assessment and criticality-based replacement and renewal program for the distribution system	D	X		
Dedicated Water Quality Sampling Stations – Install the planned 22 dedicated monitoring stations, and plan for the installation of additional stations	A		X	
GIS – Emphasize the entry of data from the water system into GIS	B	X		
Low Priority				
Strengthen coordination with fire districts performing hydrant testing and maintenance to preclude system disturbances	C			X
Water Quality Goals - Adopt HDR's Recommended Water Quality Goals	B		X	
Water Loss Control – Develop a prioritized plan for reducing loss, including reenergizing the preventive leak detection program. Consider using the new standard IWA/AWWA method for determining water loss	B			X

Development Levels:
A – Minor modifications to existing program
B – Moderate strengthening to existing program
C – Significant strengthening to existing program
D – No existing program, needs to be developed

The DSOP process has proven beneficial to Winston-Salem City/County Utilities Commission, and has resulted in numerous benefits in the six short months since report completion. CCUC is continuing to systematically implement the prioritized areas for improvement, using the DSOP process as a roadmap.

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